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Bahl, Christian; Engelbrecht, Kurt; Eriksen, Dan; Nielsen, Kaspar Kirstein; Lei, Tian; Smith, Anders; Pryds, Nini

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Challenges in going from 2nd order to 1st order materials in magnetic refrigeration devices

C.R.H. Bahl, K. Engelbrecht, D. Eriksen, K.K. Nielsen, T. Lei, A. Smith and N. Pryds
Department of Energy Conversion and Storage
Technical University of Denmark
chrb@dtu.dk

Magnetic refrigeration devices rely on the utilisation of the magnetocaloric effect (MCE) present in magnetic materials. For a ferromagnet, the MCE is maximised close to the Curie temperature. Thus in order to utilise the MCE in devices, a choice of materials must be made according to the value and tunability of the Curie temperature as well as the strength of the MCE. Materials with a first order phase transition in general have a higher magnetocaloric effect than those with a second order phase transition, but the operational temperature span is much narrower. This, and complications arising from hysteresis effects and structural stability issues, has driven device development to rely mainly on second order materials, with only a few using first order materials.

A compact and highly efficient, but also versatile, magnetocaloric prototype device has been constructed at the Technical University of Denmark [1]. The performance of gadolinium alloys, all second order materials, will be presented. Based on this the path towards utilising first order materials in devices will be discussed in relation to materials properties and small scale testing.

It is well known that first order materials are often brittle and will easily break when repeatedly taken through the structural first order transition. This makes them challenging to process into the desired shapes, thus limiting the possibility of controlling the convective heat transfer and pressure drop properties of the solid structures. In addition, regenerator performance may be severely reduced if the morphology is not chosen to minimise the magnetostatic demagnetisation [2]. Recent modelling work has demonstrated how the narrow peak in the magnetocaloric effect will make performance very sensitive to the accurate layering of the materials [3]. A large number of materials and a very high precision in the Curie temperatures are required from the materials manufacturer to meet these needs. Also, even small values of hysteresis have been shown to have a severe impact on the performance of materials in devices [4]. These issues and their implication on the device performance will be discussed.

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